We conclude that diclofenac as prescribed in our study can be recommended, for it provides morphine-sparing analgesia and improves postoperative adverse effects such as sedation and nausea. These are important considerations in facilitating recovery from surgery and anaesthesia.

References


Conclusions. During mechanical ventilation, dDown and the SPV may serve as minimally invasive indicators of preload. The retransfusion stage that follows significant blood loss may be associated with deterioration in LV function.

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Keywords: arterial pressure, measurement; blood, loss; heart, echocardiography; pig

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One of the suggested methods for assessing cardiac preload in mechanically ventilated patients is arterial pressure waveform analysis.1 The increase in intrathoracic pressure during mechanical ventilation normally causes a biphasic change in left ventricular (LV) output, which is reflected in a similar way in arterial blood pressure (BP).1–3 An early elevation in BP, termed delta up (dUp), reflects augmentation of LV stroke volume (SV), and is normally followed by a later decrease in BP, which is termed delta down (dDown). The difference between the maximal and minimal values of the systolic BP during one mechanical breath is termed the systolic pressure variation (SPV). The SPV and dDown were found to correlate with the degree of blood removal during experimental haemorrhage2 and during surgery,4 and with echocardiographic estimates of LV filling in post-operative patients.5 Moreover, SPV and dDown were found to predict the haemodynamic response to volume loading better than the pulmonary artery occlusion pressure or LV end-diastolic area in mechanically ventilated septic patients.6 dUp was, in turn, found to become more prominent during hypovolaemia7 and during experimental congestive heart failure.3 Recently, however, Dalibon and colleagues7 questioned the usefulness of dDown in assessing the degree of blood loss, it was not a better measure than mean arterial BP.

The aim of our study was to examine the correlation between parameters of arterial pressure waveform analysis to echocardiographic estimates of cardiac preload and function during graded haemorrhage and retransfusion.

Methods and results

Seven German Landrace pigs (30.4 (6.8) kg) were anaesthetized with sodium pentothal 10 mg kg−1, the trachea intubated and the lungs ventilated with a tidal volume of 12 ml kg−1 (peak inspiratory pressure 15–18 cm H2O), 8–12 min−1 (PeCO2 35–40 mm Hg), FrO2 0.5. Anaesthesia was maintained with halothane and pancuronium. A thermodilution pulmonary and a femoral arterial catheter were inserted. The animals were bled by increments of 5% of their blood volume (estimated to be 75 ml kg−1), up to a blood loss of 30%, following which the shed blood was retransfused over 4–5 min.

Haemodynamic measurements were made at baseline and 2–3 min after each change in blood volume. SPV was calculated as a mean over five consecutive mechanical breaths. dUp and dDown were measured as the difference between the value of systolic BP during 5 s of apnoea and its maximal and minimal values, respectively, during the respiratory cycle immediately preceding the apnoeic period. SPV, dUp, and dDown were expressed as percentages of systolic BP during apnoea.

Echocardiographic measurements were performed by a cardiologist who was blinded to the haemodynamic data. More details of the echocardiographic methods used in the study may be found elsewhere.8 Changes in the variables during the experiment were evaluated by analysis of variance for repeated measures. Coefficients of linear correlation between the LV end-diastolic volume (LVEDV) and the SPV, dDown, central venous pressure (CVP), and pulmonary artery occlusion pressure (PAOP) for each animal were derived by calculation of the mean r-values by reversed Fisher transformation.

Changes in the haemodynamic variables during the experiment are presented in Table 1. The gradual nature of the haemorrhage caused no significant changes in the arterial BP, and a significant decrease in the mean SV occurred only after 20% haemorrhage. CVP, PAOP, and LVEDV decreased, and %SPV and %dDown increased from the very early stages of haemorrhage. Following retransfusion, LVEDV returned to its baseline value. SV and left ventricular ejection fraction (LVEF) significantly decreased. dUp increased significantly, as did left ventricular end-systolic wall stress (ESWS). Changes of PAOP, CVP, and %SPV and %dDown correlated significantly with LVEDV (r values of 0.76, 0.77, -0.77, and -0.82, respectively).

Comment

The early steps of graded haemorrhage create an occult hypovolaemia, which cannot be detected by conventional monitoring. In this set up SPV and dDown have been shown again, as in previous studies,2,4,5 to be sensitive indices of LVEDV, and to change significantly at the very early stage of blood loss. The results are contrary to those of Dalibon and colleagues who found dDown to be of less benefit than arterial BP itself in reflecting the degree of haemorrhage.7 However, in that study haemorrhage caused a severe
reduction in arterial BP, and dDown was not expressed as per cent of BP as recommended.1

The retransfusion stage was associated with a global deterioration in LV function, which was reflected by the sharp decrease in LVEF. This phenomenon may have been caused by an elevation of afterload and/or by myocardial depression. Indeed, although no significant changes of systemic vascular resistance (SVR) occurred, ESWS, a mechanically ventilated patients.

Table 1 Cardiovascular parameters following haemorrhage and retransfusion. Values are presented as mean (SD). *P<0.05, **P<0.01, ***P<0.005 compared with baseline values. PAP, systolic pulmonary artery pressure

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
<th>Retransfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP (mm Hg)</td>
<td>113 (7)</td>
<td>111 (7)</td>
<td>112 (7)</td>
<td>114 (12)</td>
<td>114 (13)</td>
<td>109 (6)</td>
<td>108 (7)</td>
<td>127 (11)**</td>
</tr>
<tr>
<td>Heart rate (beat min⁻¹)</td>
<td>117 (19)</td>
<td>109 (7)</td>
<td>109 (5)</td>
<td>116 (11)</td>
<td>127 (22)</td>
<td>139 (25)*</td>
<td>149 (29)*</td>
<td>138 (21)*</td>
</tr>
<tr>
<td>PAP (mm Hg)</td>
<td>28 (8)</td>
<td>27 (5)</td>
<td>25 (6)</td>
<td>26 (7)</td>
<td>25 (7)</td>
<td>25 (7)</td>
<td>24 (7)</td>
<td>33.1 (6.8)*</td>
</tr>
<tr>
<td>PAOP (mm Hg)</td>
<td>12.3 (3.2)</td>
<td>11.4 (3.0)**</td>
<td>10.6 (3.6)*</td>
<td>10.4 (4.3)*</td>
<td>9.4 (5.3)*</td>
<td>8.4 (3.6)**</td>
<td>8.1 (3.8)**</td>
<td>14.4 (2.9)</td>
</tr>
<tr>
<td>CVP (mm Hg)</td>
<td>9.9 (3.1)</td>
<td>8.9 (3.5)*</td>
<td>8.0 (3.8)**</td>
<td>7.1 (4.7)**</td>
<td>6.9 (3.9)**</td>
<td>6.1 (4.2)**</td>
<td>5.9 (4.0)**</td>
<td>12.0 (3.5)</td>
</tr>
<tr>
<td>SV (ml)</td>
<td>32.9 (10.0)</td>
<td>32.2 (9.6)</td>
<td>30.9 (8.1)</td>
<td>31.3 (13.6)</td>
<td>27.6 (12.8)*</td>
<td>24.0 (8.7)*</td>
<td>20.8 (9.3)*</td>
<td>26.4 (10.1)*</td>
</tr>
<tr>
<td>LVEDV (ml)</td>
<td>62.8 (20.3)</td>
<td>54.9 (18.3)*</td>
<td>51.9 (14.8)**</td>
<td>52.3 (16.6)*</td>
<td>50.1 (14.9)**</td>
<td>44 (14.8)**</td>
<td>37.5 (12.4)**</td>
<td>65.9 (16.7)</td>
</tr>
<tr>
<td>SVR (dyne s⁻¹ cm⁻⁵)</td>
<td>1751 (659)</td>
<td>1799 (494)</td>
<td>1846 (461)</td>
<td>1945 (711)</td>
<td>2114 (931)</td>
<td>2074 (751)</td>
<td>2241 (900)</td>
<td>2198 (717)</td>
</tr>
<tr>
<td>%SPV</td>
<td>53 (10)</td>
<td>52 (8)</td>
<td>51 (9)</td>
<td>55 (12)</td>
<td>57 (4)</td>
<td>55 (15)</td>
<td>55 (20)</td>
<td>38.9 (11.3)**</td>
</tr>
<tr>
<td>%dDown</td>
<td>7.9 (2.9)</td>
<td>9.8 (4.0)*</td>
<td>11.5 (4.5)**</td>
<td>12.7 (4.7)**</td>
<td>15.4 (8.1)**</td>
<td>18.3 (9.4)**</td>
<td>19.0 (8.5)**</td>
<td>7.8 (5.1)</td>
</tr>
<tr>
<td>%dUp</td>
<td>7.9 (2.9)</td>
<td>7.8 (2.8)**</td>
<td>10.7 (3.9)**</td>
<td>12.2 (4.1)**</td>
<td>13.9 (5.3)**</td>
<td>17.9 (8.3)**</td>
<td>18.7 (7.2)**</td>
<td>4.0 (4.4)</td>
</tr>
</tbody>
</table>

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